Most Significant Achievements
Anton Zeilinger

The citation for the Isaac Newton Medal of the Institute of Physics (UK), whose first ever recipient Anton Zeilinger is, highlights his achievements as follows:

"For his pioneering conceptual and experimental contributions to the foundations of quantum physics, which have become the cornerstone for the rapidly-evolving field of quantum information.

It is his profound insights into the microscopic nature of reality, as described by quantum theory, and his ability to turn new concepts into innovative experiments that have excited the scientific community - as well as capturing the popular imagination.

Professor Zeilinger started his career investigating the wave nature of matter through quantum interferometry experiments with neutrons and atoms. His team later went on to demonstrate the wave-particle duality concept in large molecules such as fullerenes, exploring the frontier between quantum and classical behaviour.

He also re-visited and extended established theoretical interpretations of the quantum world. In the 1990s, he carried out a series of brilliant experiments exploring the behaviour of entangled photons. He developed a method to create for the first time entangled three-particle states - Greenberger-Horne-Zeilinger states. One of his most famous experiments using correlated photons is that of quantum teleportation, reported in *Nature* in 1997.

Zeilinger's work helped open the way to new quantum information technologies. He developed the first entanglement-based cryptographic system, and more recently worked on implementations of quantum computing using photon cluster states.

Professor Zeilinger is not only a founder and leader of optical quantum information science but is also a mentor for many young scientists who have gone on to make their mark in this exciting field."

In detail, the most important achievements of Anton Zeilinger and his group include:

- Proposal [1] and experimental verification [2] of **entanglement swapping**, the teleportation of entanglement, an important ingredient of future **quantum repeaters**.
- Experimental realization of **quantum dense coding**. This was the first ever demonstration of a protocol in quantum information where entanglement enters in a significant way. [3]
- The **world's first quantum teleportation**, a direct transfer of the quantum state of a photon to another distant photon exploiting quantum entanglement, a feature of correlated quantum systems Einstein called "spooky action at a distance". [4]
- Observation of **quantum entanglement under Einstein locality condition**, thus closing the so-called communication loophole. [5]

- Discovery and first experimental demonstration of **entanglement of more than two particles** (GHZ, Greenberger-Horne-Zeilinger states). This constitutes the maximal possible contradiction between local realism and quantum mechanics. It was also the first time that **multi-qubit-entanglement** was introduced. [6]
- The observation of **quantum interference for the most massive and complex molecules**, the so-called fullerenes (C60 and C70 molecules). [7]
- The first realization of **entangled-state quantum cryptography**. The security of the transmission of secret information is ensured by natural laws. [8]
- The realization of **quantum entanglement purification**. The quality of entanglement of photons is drastically improved, which has important applications for long-distance quantum communication. [9]
- **Quantitative decoherence experiments** with fullerenes. When quantum objects exchange information with their environment, they lose their quantum features. In the experiment, this was shown for the case of collisions and of exchange of thermal radiation. [10]
- First experimental realization of the **one-way quantum computer** and implementation of a number of protocols like **Grover's search algorithm** and **prisoner's dilemma.** [11, 12, 13]
- The **observation of self-cooling of a micromirror by radiation pressure** inside a high-finesse optical cavity provided important insights into the **transition between classical and quantum behaviour of a mechanical system** and has contributed to many fields of physics including ultra-high precision measurements and the detection of gravitational waves. [14]
- **Free-space distribution of quantum entanglement** over distances of up to **144 km** using polarization-entangled photons via a free-space link between the Canary Islands La Palma and Tenerife. [15]
- An **experimental test of non-local realism** demonstrating that a non-local model proposed by Leggett is at variance with experimental observation. Our result suggests that it may be the concept of objective realism which is at stake rather than locality by itself. [16]

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